



COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

EARLE C. CLEMENTS
COMMISSIONER OF HIGHWAYS

February 25, 1960

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

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MEMO TO: D. V. Terrell
Director of Research

The attached report, "Interim Performance Report on Morton's Gap Culvert Pipe Installation", by James H. Havens, is primarily a listing of the status of the condition of pipe still in the test and the date of failure or removal of the other sections.

Mr. Havens has prepared as background information, a brief record of the Department's practices involving pipe use for the past 10 years. He has begun with the Research Division's first study into pipe damaged by the corrosive action of acid water. This information is presented primarily because of its significance in the development of the culvert pipe test installation.

We are of the opinion that the test section is producing valuable information on the comparative service life of pipe types and coatings subjected to high concentration of corrosive liquids. There is every indication that in the next few years some of the remaining pipe sections will fail and provide complete service-life records of these pipe for the stated conditions.

The summary section of the report lists performance of individual pipe sections.

Respectfully submitted,

A handwritten signature in dark ink, appearing to read "W. B. Drake".

W. B. Drake
Associate Director of Research

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cc: Research Committee
Bureau of Public Roads (3)

Commonwealth of Kentucky
Department of Highways

Interim Performance Report

on

MORTON'S GAP CULVERT-PIPE INSTALLATION

by

James H. Havens
Assistant Director of Research

Highway Materials Research Laboratory
Lexington, Kentucky

February, 1960

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INTRODUCTION

Beginning in September, 1949, the Research Laboratory became involved in a seemingly minor investigation of culvert failures on US 60 near Ashland. The report* attributed the failures to the acidity

* Research Laboratory Memorandum Report, September 21, 1949, presented to Research Committee, December 20, 1949.

of the drainage water in the area; and, as a consequence of this, the Research Division was directed to commence a rather detailed survey of culvert conditions throughout the state. By the end of 1950, more than 13,000 culverts were examined in eastern and western Kentucky. A progress report* was presented in December, 1950. Of the 13,000 culverts,

* Progress Report No. 1 on "A Survey of Acidity in Drainage Waters and the Conditions of Highway Drainage Installations," by Havens, Young, and Field, December 1950; presented to Research Committee February 1, 1951.

296 were corrugated metal cross drains and about 20 percent of these showed advanced corrosion. An additional 859 were used as entrance pipe, of which 1.8 percent showed serious damage due to corrosion. At this point, it became apparent that plain corrugated (galvanized) culverts were in serious minority from the standpoint of a statistically comparative evaluation of average service-life of culvert types. Because of this, it was proposed in the 1950 report that a culvert test installation be made in which each type of pipe would be subjected to

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the same water. To accelerate the test, a continuous source of highly acid mine-water (pH 3.0 to 3.5) was located at Morton's Gap in Hopkins County. The installation was made April 25, 1951.

The survey was continued through 1952 to complete the coverage of the Bluegrass Area and the central portions of the state. While this work was in progress, an impromptu investigation was made of corrosive damage to concrete bridge piers, box culverts, and metal arches in Hopkins County.* A composite report of the survey work

* "Corrosion of Highway Structures in Acid-Bearing Drainage Water in Hopkins County," Research Laboratory memorandum report to the Director of Maintenance, June 21, 1952, by Jas. H. Havens.

was combined into a comprehensive documentary report in December, 1952*. This was intended to be a terminal report on the survey work,

* Report No. 2 on "A Survey of Acidity in Drainage Waters and the Condition of Highway Installations," by Jas. H. Havens, Dec., 1952.

but it included some early results from the Morton's Gap test installation. In fact, it disclosed a rather startling development: plain, galvanized, corrugated metal pipe developed critical rusting in 27 days, and the invert was completely corroded away in 82 days.

The initial provocation resulted in a statement of policy* regard-

* Bulletin No. 2043, September 7, 1949.

ing culvert types for cross drains which excluded corrugated metal pipe

but allowed the continued use of corrugated metal plate arches. Apparently this policy allowed the continued use of metal pipe for entrances. This policy was subsequently amended* to allow the use

* Bulletin No. 2053, October 5, 1949.

of corrugated metal pipe and deformed pipe on Rural Secondary projects, but this amendment provided that for maintenance of roads likely to be taken into the state system Bulletin 2043 would apply. Later it became the policy* to specify corrugated metal without alternate

* Bulletin No. 2082, December 28, 1949.

of first-class pipe except on Federal Aid Work. On Federal Aid Work, the practice of specifying alternate types was continued. This statement was made pending the outcome of Research Division's study. Engineers were also instructed therein to specify bituminous coated pipe where extreme acid conditions were known to exist.

On April 26, 1950, the Research Division, by memorandum, recommended that 19 named counties be regarded as areas where critical corrosive waters might be encountered. This recommendation prompted another statement of policy* which remained in effect until

* Bulletin 2161, Official Order No. 32730, July 7, 1950.

May 27, 1953. This policy prohibited the use of corrugated metal pipe and pipe arches in 32 named counties. In the remaining counties,

bituminous coated pipe and arches were permitted for cross drains, and uncoated metal was permitted for side entrances. Structural-plate arches were permitted advisedly in both areas.

Following the completion of Report No. 2, which the several manufacturers of pipe were invited to review and to offer arguments thereto, an interim policy statement* was issued pending further

* Bulletin No. 2517, Official Order No. 40821, May 27, 1953.

developments from the Morton's Gap installation. On projects financed wholly with state funds, corrugated metal pipe and pipe arches were excluded from use as cross drains in 32 named counties, whereas structural-plate arches could be used advisedly. In the remaining counties, bituminous coated metal pipe and arches excepting large field-assembled units were required to be bituminous coated when used as cross drains. In these same remaining counties, plain galvanized metal was authorized for use on side entrances. On Federal Aid Secondary projects, the provisions were identical to those already cited. On Federal Aid Primary projects or Federal Aid Urban Projects, both plain and bituminous coated metal were prohibited as cross drains in all counties whereas plain galvanized metal pipe were admissable for side entrances in the un-named counties.

The above policy was superseded in 1957*. The new provisions

* Bulletin No. 2829, Official Order No. 53104, September 17, 1957.

are quoted as follows:

"Hereby it is ordered that the procedure stated below be followed until further notice for the specifying and use of cross-drain and side entrance pipe and pipe arches.

"Any of the types of culvert pipe and pipe arches as covered by the Department's Standard Specifications for Road and Bridge Construction, Edition of 1956, and approved amendments thereto, may be used in all counties on State or Federal-aid projects, subject to design requirements as may be determined by the State Highway Engineer and further subject to the conditions and requirements acceptable to the U.S. Bureau of Public Roads.

"All factory-riveted corrugated sheet metal pipe and pipe arches and all field assembled corrugated structural plate pipe and pipe arches are to be bituminous coated in accordance with the requirements of Article 7.8.6 or Article 7.8.7 of the Department's Standard Specifications Edition of 1956, and approved amendments thereto."

The above order was subsequently superseded* by the following

* Bulletin No. 2933, Official Order No. 59948, June 13, 1959.

statement:

"Hereby it is ordered that the procedure shown below be followed until further notice for the specifying and use of side entrance pipe.

"Bituminous coated galvanized factory riveted corrugated metal pipe and pipe arches and reinforced concrete pipe shall be used as alternates on all projects for side entrance structures in the following counties:

"Boyd, Carter, Johnson, Floyd, Martin, Pike, Letcher, Harlan, Bell, Knox, Whitley, McCreary, Perry, Magoffin, Morgan, Leslie, Menifee, Elliott, Lee, Henderson, Ohio, Muhlenberg, Hopkins, Webster, Union, Daviess, Pulaski, Knott, Laurel, Breathitt, Clay, and Butler.

"Plain galvanized factory riveted corrugated metal pipe and pipe arches and reinforced concrete pipe shall be used as alternates and on all projects for side entrance pipe in the remaining counties."

The above stated policy was incorporated into an amendment*

* Amendment No. 34 to 1956, Standard Specifications, Aug. 26, 1959.

to the 1956 Standard Specifications, is quoted below:

ENTRANCE PIPE

Page 403, Article 6.22.2, "Materials". Delete the entire paragraph and substitute as follows:

"Unless otherwise specifically provided on the plans or in the proposals, entrance pipe shall be either reinforced concrete pipe, or corrugated metal pipe or pipe-arches.

"The installation of reinforced concrete pipe meeting the applicable requirements of Article 7.8.0 (Amendment No. 16) will be allowed on all projects.

"The installation of corrugated metal pipe or pipe-arches meeting the applicable requirements of the Standard Specifications for Corrugated Metal Culvert Pipe, AASHTO Designation: M36, will be allowed in side entrances only, on all projects which are not located in certain specified areas requiring bituminous coating and paving for metal pipe.

"The installation of bituminous coated and paved corrugated metal pipe or pipe-arches meeting the applicable requirements of Article 7.8.0 (Amendment No. 16) will be required, when used for entrance structures, on all projects located in certain areas specified by Department policy.

"The inlet and outlet ends of all corrugated metal pipe and pipe-arches and reinforced concrete elliptical pipe shall be reinforced in a manner approved by the Engineer.

"In addition to the preceding requirements, corrugated metal pipe-arches and reinforced concrete elliptical pipe shall be fabricated to the applicable dimensions indicated on Standard Drawing No. 11.23."

Originally, 1948, plain galvanized metal pipe were allowed on Rural Secondary roads. These roads were not covered in the 1950 and 1951 surveys because the Rural Secondary program was new, and it was assumed that they had not been in service long enough to be significant. This proved to be a rather erroneous assumption because the Maintenance Division began to receive complaints about failures within about 2 years. Subsequently, bituminous coated pipe were required at least in critical areas.

Because bituminous coated pipe had not been required or used extensively as cross drains prior to the 1950-51 surveys, there were located under railroads or had been used as replacements for failed culverts. From this meager information, augmented by some service histories from other states, it was estimated in the December 1952 report that the probable life of the bituminous coating on metal pipe would be about 15 years and that the life of the metal pipe in areas of extreme corrosivity would be determined largely by the life of the coating.

After the earliest installations of bituminous coated pipe on Rural Secondary roads had been in service about 4 or 5 years, the Research Division made a survey* of them, which disclosed: (1) a

* An Inspection of Bituminous Coatings and Pavements on Corrugated Metal Culverts, " by E. M. West, November 1954.

frequency of damage due to fire, (2) cracking and peeling where exposed to sunlight, and (3) improper positioning of paved inverts during installation. This report presented a number of observations

from the Morton's Gap test installations, and it thus served as a status report on that project. Also, while that survey was in progress, a number of large structural-plate arches were discovered which were showing serious corrosion and even failure. Since these installations represented considerable expenditures and were only a few years old, a survey of these structures was made and reported in 1957*. This report included observations on 86 unpaved structures

* "A Survey Inspection of Plain Corrugated Metal Pipe Arches and Multi-Plate Pipe Arches in Kentucky," by E. M. West, March, 1957.

located mostly in the eastern and central parts of the state, of which 60 percent had rusted or corroded to a considerable degree. This survey led to the adoption of policies concerning paving and coating of these structures also and which have now been incorporated into Amendments No. 13 and 14 to the Department's 1956 Standard Specifications.

The preceeding story attempts to document some of the circumstances surrounding the Morton's Gap installation and to reflect the significance of it. Actually, the purpose of the installation was to compare the durabilities of concrete pipe and bituminous coated, galvanized, corrugated metal pipe under extreme conditions of acidity. It had been well established previously that plain galvanized metal was practically worthless under such conditions*. Therefore, galvanized

* Note: Report No. 2 indicates that the life-expectancy of plain galvanized metal pipe under milder conditions may vary from a relatively few years to many years depending upon continuous or intermittent wetting.

metal and vitrified clay were included in the test merely to demonstrate two extremes. It had been observed in the 1950 survey that concrete pipe made with siliceous gravel aggregate was more resistant to severely acid conditions than pipe made with limestone. Originally, two sections of pipe containing gravel aggregate were installed. A section of concrete pipe containing limestone aggregate was installed September 24, 1954. Bituminous coated pipe, coated and paved according to the Kentucky Specifications current at that time, plain galvanized pipe, and other variously coated and paved pipe were included in the original installation. A lay-out of the installation is shown in Fig. 1.

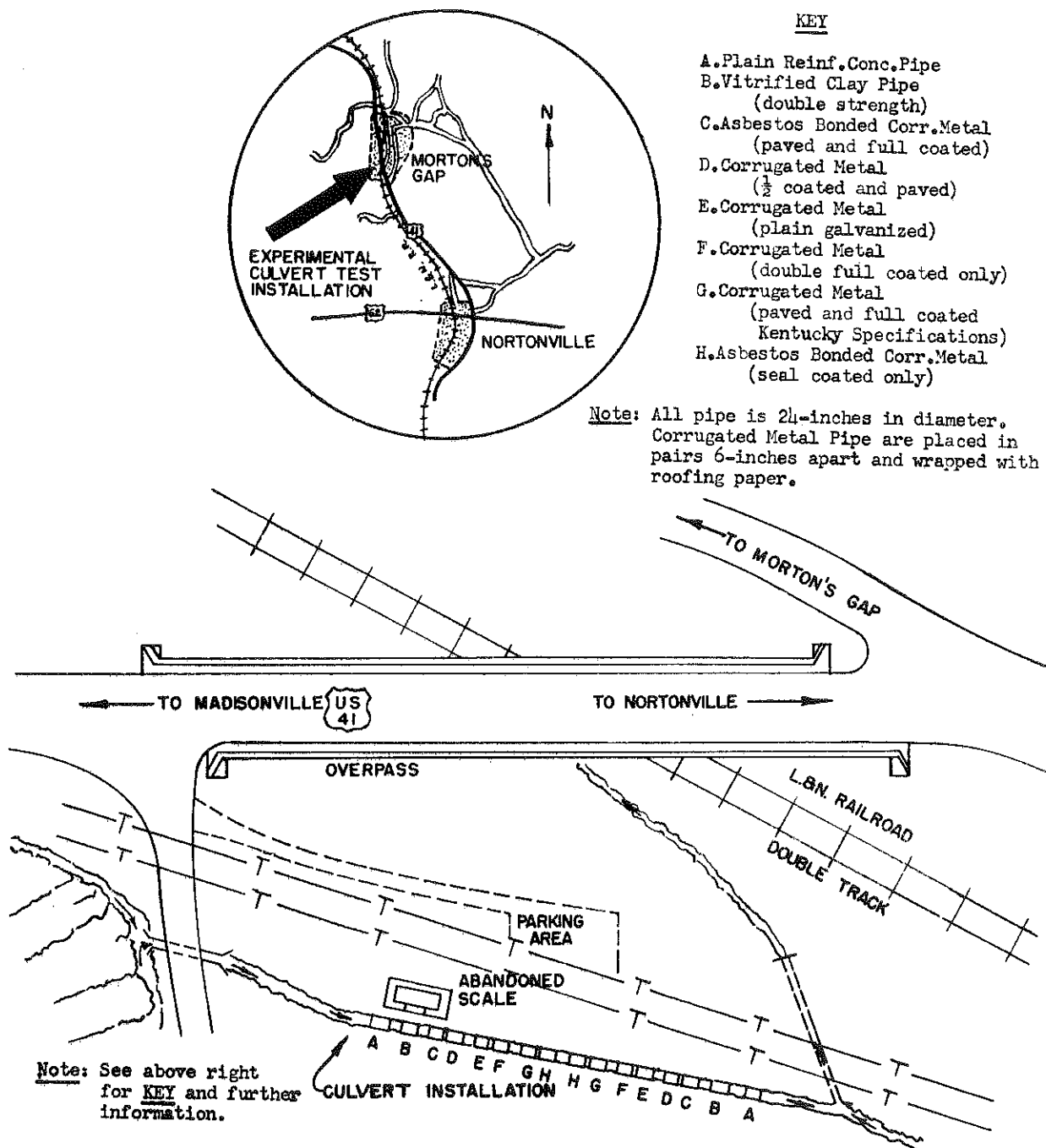


Fig. 1. Plan-View of Experimental Culvert Installation.

CHRONOLOGY

- April 25, 1951. Date of installation. Specific resistance of water - 280 ohms.
- May 22, 1951. Date of first inspection. Specific resistance of water - 260 ohms. Spelter gone from plain galvanized metal sections.
- July 16, 1951. Water tested 235 ohms. Invert eaten out of plain galvanized metal sections. Concrete showed slight etching.
- August 20, 1951. Water tested 240 ohms.
- October 18, 1951. Routine inspection. No significant changes.
- March 9, 1952. Water tested 300 ohms.
- April 15, 1952. Heavy rain dislodged several sections of pipe and deposited silt in channel.
- April 29, 1952. Installation restored. Galvanized metal sections not replaced, water tested 290 ohms.
- June 18, 1952. Routine inspection, no significant changes.
- August 4, 1952. Water tested 268 ohms.
- August 28, 1952. Routine inspection, no changes noted.
- October 5, 1952. Water tested 265 ohms. Concrete pipe beginning to show visible evidence of progressive corrosion. Aggregate exposed in the invert, but no appreciable reduction in thickness observed.
- July 7, 1953. Water tested 267 ohms. No changes noted.
- September 7, 1953. Full double coating gone in invert of one (upstream) section of pipe, metal corroding. Water tested 280 ohms.
- July 22, 1954. Full double coated section removed with invert eaten out.

August 18, 1954. Water tested 275 ohms. Pipe section in the lower half of the installation were heavily silted. The pipe removed and reset. Downstream channel cleared to prevent silting if possible.

September 21, 1954. Concrete with limestone aggregate installed.

August 9, 1955. Water tested 275 ohms.

April 24, 1956. Several sections of pipe stolen and recovered by State Police. Installation restored.

September 29, 1957. Water tested 325 ohms.

November 6, 1957. Removed one section, full coated, and paved, Kentucky Specifications, and one section with double coating and paving.

May 28, 1958. Water tested 345 ohms.

July 1, 1958. Water tested 300 ohms, pH 3.2 to 3.6. Additional pipe and plates installed by Armco.

February 2, 1959. Water tested 355 ohms. Two sections corrugated metal, Armco aluminized, removed. Two section, corrugated metal, galvanized, heat-treated removed.

February 16, 1959. Oral report to Research Committee (illustrated).

July 21, 1959. Corrugated metal, porcelainized inside, removed. Corrugated metal, galvanized, removed, two sections.

January 28, 1960. Water tested - pH 3.3, last condition inspection.

SUMMARY

Corrugated Metal - Plain Galvanized (2 Sections) - Installed April 25, 1951. The spelter was missing and perforated, May 22, 1951, invert had rusted out by July 16, 1951. These sections were removed in April, 1952.

Corrugated Metal - Double Coated, No Paving (2 Sections) - Installed April 25, 1951. One section was removed in July, 1954. The other section was perforated by 1955, and was removed in November 1957.

Corrugated Metal - Full Coated and Paved, Kentucky Specification - Installed April 25, 1951 and removed November, 1957.

Corrugated Metal - Asbestos Bonded and Sealed - Installed April 25, 1951. There were perforations along the flow line in 1955. The section was stolen in 1956, found and replaced with the original invert at the top. In 1958, the new invert had rusted through and the section was removed, July 21, 1959.

Concrete-River Gravel (2 Sections) - Installed April 25, 1951. Mortar along the flow line has been etched approximately 3/16 inch deep exposing the aggregate, by January 28, 1960 (see Fig. 2).

Vitrified Clay (2 Sections) - Installed April 25, 1951. No visible deterioration by January 28, 1960.

Corrugated Metal - Asbestos Bonded, Coated and Paved (2 Sections) - Installed April 25, 1951. By January 28, 1960, the coating on the exterior top surface had cracked severely due to sunlight and peeled off at the inlet and outlet ends. There was no apparent sign of deterioration within the section other than discoloration along the flow line and cracking of the coating at the inlet and outlet invert.

Corrugated Metal - Asbestos Bonded and Sealed - Installed April 25, 1951. By January 28, 1960, the exterior coating was missing at points, rusting taking place. Deep cracks had formed in the invert coating due to contraction. There was no evidence of deterioration of the metal.

Corrugated Metal - Full Coated and Paved, Kentucky Specification - Installed April 25, 1951. By January 28, 1960, the coating had cracked and was missing in sections on the exterior top surface. Long cracks had developed along the paving of the invert with advanced tubercular rust on the exposed metal. Failure seems imminent.

Corrugated Metal - 1/2 Coated and Paved (2 Sections) - Installed

April 25, 1951. On January 28, 1960, there was no evidence of deterioration of exterior surface. There were portions of the coating and paving missing along the invert with advanced tubercular rusting and holes through the metal at the inlet and outlet.

Concrete - Limestone Aggregate - Installed September 21, 1954. The mortar and aggregate have been etched out to a depth of approximately 1/16 inch or more, January 28, 1960 (see Fig. 3).

Corrugated Metal - Porcelain Enamelled, Inside Only - Installed July 1, 1958, this section had to be removed July 21, 1959, due to extreme deterioration.

Corrugated Metal - Asbestos Bonded, Coated and Paved - Installed April 25, 1951. Severe cracking of the coating has taken place on the exterior surface due to sunlight, the paving is missing along approximately 1/3 of the invert, with advanced tubercular rust and holes in the metal in some areas, as of January 28, 1960.

Corrugated Metal - Blue Porcelainized Enamelled, Full Coated, Aluminized, Type 2 - Installed July 1, 1958, this section had failed completely and was removed July 21, 1959.

Corrugated Metal - Structural Plate, Stainless Steel - 0.078 inch gage, installed July 1, 1958. There was severe rusting along the flow line, near tubercular stage. No holes were noticed January 28, 1960.

Corrugated Metal - Structural Plate Section, Stainless Steel - 0.135 inch gage, installed July 1, 1958. There was severe rusting near tubercular stage along flow line, but no holes as of January 28, 1960.

Corrugated Metal - Plastisol Coated (2 Sections) - Installed July 1, 1958. No evidence of deterioration was observed. One section had a slight tear in the Plastisol coating which exposed the undercoating, but no rusting was observed since the metal has not been exposed.

Corrugated Metal - Armco Aluminized (2 Sections) - Installed July 1, 1958. These two sections failed and were removed February 2, 1959.

Corrugated Metal - Galvanized, Heat Treated (2 Sections) - Installed
July 1, 1958. The two sections failed and were removed February 2, 1959.

Corrugated Metal - Galvanized (2 Sections) - Installed July 1, 1958.
The two sections failed and were removed July 21, 1959.



Fig. 2. Condition of Concrete Pipe Containing Siliceous Gravel Aggregate, as of July 21, 1959.

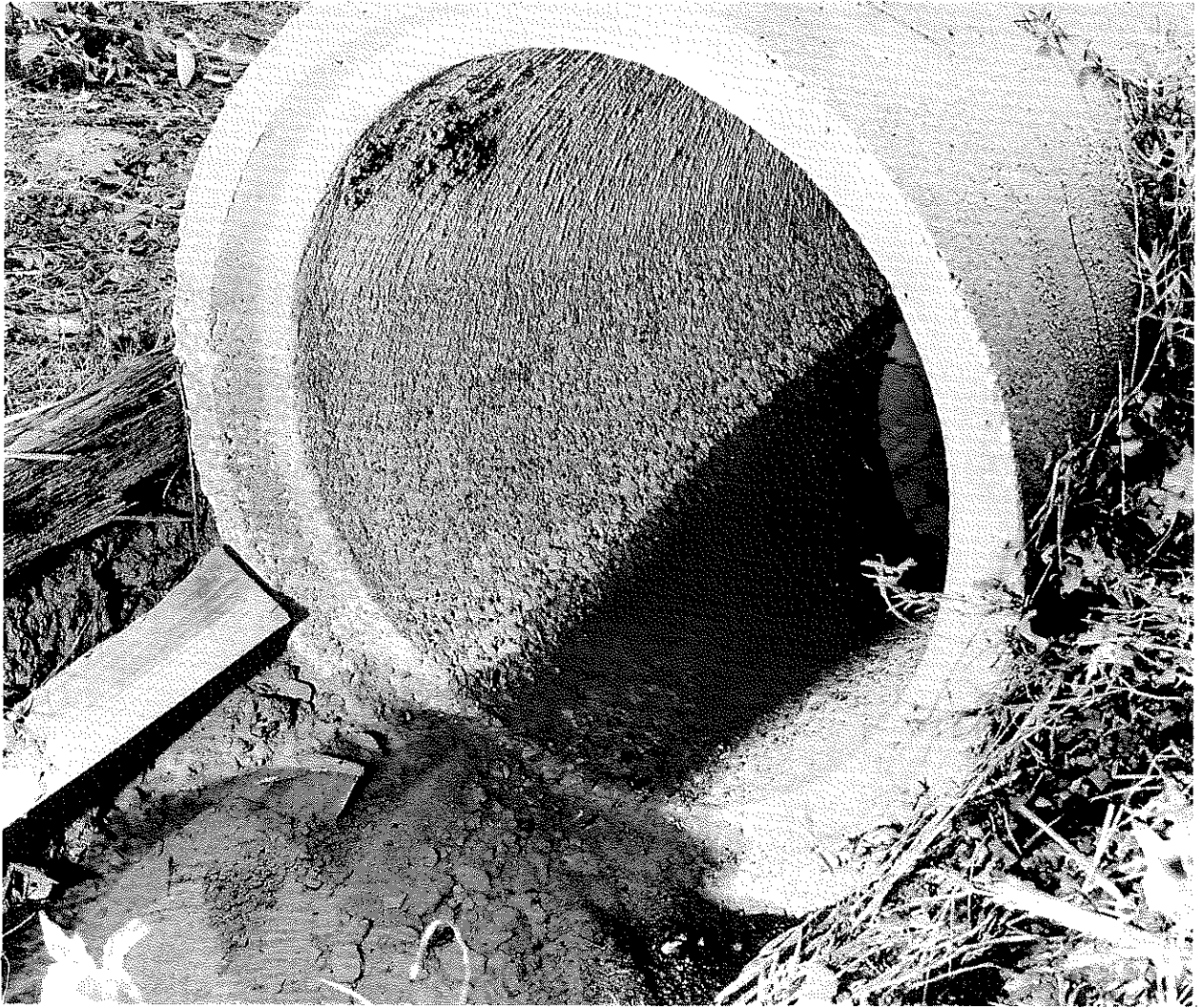


Fig. 3. Condition of Concrete Pipe Containing Limestone Aggregate, as of July 21, 1959.